The first step in selecting a clutch or brake is to IDENTIFY THE TYPE OF APPLICATION:

- **INFREQUENT ENGAGEMENT, e.g. power take-offs, compressor drives**
- **HIGH INERTIA ACCELERATION OR EMERGENCY "E" STOP, e.g. high inertia fans, coal pulverizers**
- **FREQUENT OR CYCLIC STARTS AND STOPS,e.g. punch presses, shears**
- **CONTINUAL SLIP OR CONSTANT TENSIONING, e.g. steel unwinders, paper tensioners**

Before these four categories are individually dealt with, some fundamentals in connection with clutch/brake selection will be discussed. These fundamentals, including WK^2 and placement of the clutch in drive, are used in many (though not all) applications.

1) WK^2, ROTATIONAL INERTIA OF A UNIT (also called WR^2). It is a measure of the unit's resistance to rotational speed change. Hence, WK^2 is a crucial factor in selection of a majority of clutches and brakes involving a change of RPM.

The torque required to accelerate a rotating body is the product of its mass moment of inertia (I) and the angular acceleration (**a**):

$$T=I\mathbf{a}$$

where $I=mK^2$

K=radius of gyration of the body

(for a rotating solid cylinder, K=0.71 X radius)

$$m=\text{mass}=\frac{W}{g}$$

W=weight of the body

g=acceleration due to gravity, a constant

$$WK^2=mgK^2=(mK^2)g=Ig$$

$$\text{or, } I=\frac{WK^2}{g}$$

$$\text{Torque } T=\frac{WK^2\mathbf{a}}{g}$$

$$\text{Since } \mathbf{a}=\frac{\Delta RPM}{t}$$

Where ΔRPM= difference between initial RPM and final RPM

t=time lapse to bring from initial to final speed

$$T=\frac{WK^2(\Delta RPM)}{gt}$$ **Formula 1**

The WK^2 value of a system determines the time required to accelerate the system to a desired speed, given a certain torque.

If the proper units are introduced,

1E

$$T=\frac{WK^2\,(\Delta RPM)}{25.6\,(t)}$$

Where T (InLB), WK^2 (Lb Ft^2), t (sec)

1M

$$T=\frac{WK^2\,(\Delta RPM)}{9.55\,(t)}$$

Where T (NM), WK^2 (KgM^2), t (sec)

The WK^2 of every rotating part that the brake must stop or the clutch must bring to speed, including it's own inertia, must be accounted for in this calculation.

WK^2 values of all Carlson Co. clutches and brakes are given in this ENGINEERING SECTION.

There is also a page in this section that lists WK^2 of steel discs.

If any part of the load is to operate at a speed other than clutch speed, WK^2 must be compensated by means of the formula:

Formula 2

$$WK^2_e=WK^2_a\left[\frac{RPM}{RPM_c}\right]^2$$

WK^2_e=equivalent or reflected WK^2 referred to clutch speed

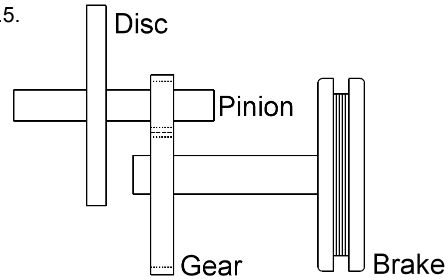
WK^2_a=actual WK^2 of load

RPM=speed of load

Rpm_c=speed of clutch

EXAMPLE:

Size a CARLSON CO. brake to stop a disc 13” (330 mm) diameter and 1 1/4” (32 mm) thick revolving at 2,000 RPM on a 2” (50 mm) diameter shaft 15” (380 mm) long. The brake is to be mounted on a 500 RPM shaft of 2 ½” (63.5 mm) diameter and 15” (380 mm) length. The gear on the high speed shaft has a WK^2 value of .015 $LbFt^2$ (.0006 KgM^2). The WK^2 VALUE of the gear on the slow shaft is 4 Lb Ft^2 (.1687 KgM^2). The system must be stopped within 1/5 second. Air pressure available is 90 PSI. The customer requires a service factor of at least 1.5.



SOLUTION:

The brake must stop the load inertia within 1/5 second. First, a rough estimate of its torque requirement can be made using Formula 1:

ENGLISH	METRIC
$T = \dfrac{WK^2 \Delta RPM}{25.6\ (t)}$	$T = \dfrac{WK^2 \Delta RPM}{9.55\ (t)}$

Total WK^2 of components on high speed shaft:

	English	Metric
WK^2 of disc*=5.58X1.25	= 6.872	= .2914
WK^2 of 2” shaft*=.0031X15	= .046	= .0018
WK^2 of gear	= .015	= .0006
	6.933 Lb Ft^2	.2938 KgM^2

WK^2 of high-speed shaft reflected to brake shaft (using Formula 2):

	English	Metric
$6.933 \left[\dfrac{2000}{500}\right]^2$	= 110.930	= 4.7008
WK^2 of gear	= 4.000	= .1687
WK^2 of 2 ½" shaft*	= .113	= .0047
Total WK^2 of the system to be stopped (rated at brake speed)	115 $LbFt^2$	4.8742 KgM^2

$T = \dfrac{115\ (500)}{25.6\ (.2)} = 11{,}230$ In Lb

$T = \dfrac{4.8742\ (500)}{9.55\ (.2)} = 1{,}275$ NM

A Carlson Co. BK model brake is suitable for this application. The torque rating of a 12” brake at 90psi is 19,588 In Lb. (2,213 NM) This allows a service factor $= \dfrac{19{,}588}{11{,}230} = 1.74$ $= \dfrac{2{,}213}{1{,}275} = 1.74$

**From table “WK2 of steel Disc.”*

A Carlson Co. 12BK can be tentatively selected for this application. The final selection can not be made until after including the WK^2 of the brake in the calculation.

WK^2 of rotating parts of a 12BK brake=8.47 Lb Ft^2 (.3573 KgM^2)

∴Total WK^2 of the system becomes 115 + 8.47 =123.47 Lb Ft^2 (4.8742 + .3573 = 5.23 KgM^2)

Now the time required to stop the system can be calculated by rewriting Formula 1:

$t = \dfrac{WK^2 \Delta RPM}{25.6\ (T)}$

$= \dfrac{123.47\ (500)}{25.6\ (19{,}588)}$

$= .123$ sec.

Service Factor $= \dfrac{.2}{.123} = 1.6$

$t = \dfrac{WK^2 \Delta RPM}{9.55\ (T)}$

$= \dfrac{5.23\ (500)}{9.55\ (2{,}213)}$

$= .123$ sec.

Service Factor $= \dfrac{.2}{.123} = 1.6$

The Carlson Co. 12BK brake will be suitable for this application.

2) SERVICE FACTOR FOR EVALUATING TORQUE REQUIREMENTS:

The type of prime mover driving the system strongly influences the choice of the clutch.

(A) **Light duty** or a steady power source with no shock or overloads:
A service factor of 1.5 is typical for these applications.
(B) **Normal duty** or a steady power source with occasional surge and/or shock or overload of moderate size: A service factor of 2.0 is recommended.
(C) **Heavy duty** or equipment with severe shock loads, high surges, continual overloads, or pulsating power sources: Service factor for heavy duty clutches should be a least 3.

3) LOCATION OF THE CLUTCH

The moderate speed shaft is, in most cases, the best place to install the clutch; providing a good balance between clutch durability and initial expense.
The clutch on the high speed shaft will be smaller in size and thus have less dissipation capacity and lining area. The clutch required on the low-speed shaft will be large and relatively expensive.
A clutch located on a medium speed shaft will have few balance or bearing failure problems.
The diameter of the mounting shaft must be verified to lie in the range between the minimum and maximum bore sides of the chosen clutch given in this catalog.

HEAVY DUTY INDUSTRIAL AIR CLUTCHES

WEIGHT (W) INERTIA (WK^2)

CLUTCH SIZE (INCHES)	MODEL CW (ONE OUTSIDE PLATE)*				MODEL CR (TWO OUTSIDE PLATES)**				ALL MODELS TORQUE ASSY.			
	W		WK^2		W		WK^2		W		WK^2	
	Lb	(Kg)	Lb Ft^2	(KgM^2)	Lb	(Kg)	Lb Ft^2	(KgM^2)	Lb	(Kg)	Lb Ft^2	(KgM^2)
8.5	8.4	3.8	0.92	.0388	19.0	8.6	2.10	.0886	10.3	4.7	0.70	.0295
10	10.9	4.9	1.59	.0670	23.9	10.9	3.43	.1447	15.0	6.8	1.35	.0569
12	18.0	8.2	3.80	.1602	40.5	18.4	8.47	.3574	20.8	9.4	2.79	.1176
14	26.0	11.8	6.90	.2910	52.0	23.6	12.45	.5253	32.0	14.5	5.90	.2488
16	37.0	16.8	12.40	.5230	76.9	34.9	23.16	.9773	41.1	18.7	9.57	.0436
18	48.0	21.8	20.57	.8676	102.0	46.3	40.00	1.688	50.0	22.7	14.64	.6175
20	70.5	32.0	37.74	1.591	145.5	66.1	71.84	3.031	73.5	33.4	26.30	1.109
22	85.4	38.8	54.02	2.278	174.5	79.2	102.60	4.329	93.5	42.4	40.10	1.619
25	134.9	61.2	110.29	4.652	266.9	121.2	199.90	8.435	136.0	61.7	76.05	3.208
28	189.0	85.8	182.80	7.710	384.0	174.3	357.60	1.509	185.5	84.2	122.20	5.154
32	260.0	118.0	334.60	14.11	550.0	249.7	667.00	2.814	267.5	121.4	233.80	9.861
36	390.5	77.3	618.80	26.10	824.0	374.1	1208.40	5.099	430.0	195.2	363.28	15.32

**Includes Pressure Plate & Cap Screws and Spacers.*
***Includes Pressure Plate, Backplate, Cap Screws and Spacers.*

SHOE BRAKE DRUM

WEIGHTS (W) lbs. **INERTIA (WK^2) Lb Ft^2**

MODEL SIZE INCHES	BORE DIAMETER		WEIGHT		WK^2	
	In	mm	Lb	Kg	Lb Ft^2	KgM^2
7	2.40	60.96	16.2	7.4	1.152	.0485
10	3.00	76.20	37.3	16.9	4.740	.1999
14	3.00	76.20	92.4	41.9	15.590	.6575
18	3.00	76.20	158.9	72.1	46.060	1.943
24	4.00	101.60	444.5	201.8	232.600	9.811

APPLICATION CATEGORIES:

Infrequent engagement is a common application. A machine falls into this category if it is of relatively low inertia and cycles at a rate of less than seven times per hour. The clutch must disconnect the prime mover from the machine at irregular intervals. The foremost criterion is estimating clutch torque based on rated horsepower of the prime mover:

$$T = P/RPM \qquad \text{Formula } \mathbf{3}$$

3E

$$T = \frac{63{,}025\ HP}{RPM}$$

Where T = (In Lb)

3M

$$T = \frac{5{,}310\ KW}{RPM}$$

Where T = (NM)

The above method is not valid when the application demands frequent engagements, prolonged acceleration and/or deceleration periods, or high inertia loads.

If the unit is to be a brake, it is often required to bring the load to a stop in an acceptable period. The time in seconds required to accelerate or decelerate a rotating mechanism:

$$t = \frac{WK^2\ (\Delta RPM)}{gT} \qquad \text{Formula } \mathbf{4}$$

4E

$$t = \frac{WK^2\ (\Delta RPM)}{25.6\ (T)}$$

Where
t (sec), WK^2 (Lb Ft^2), T (In Lb)

4M

$$t = \frac{WK^2\ (\Delta RPM)}{9.55\ (T)}$$

Where
t (sec), WK^2 (KgM^2), T (NM)

In some applications the clutch is performing load work while bringing the load inertia up to speed. In such cases, the clutch is required to not only bring the inertia of the load (flywheel, etc.) to speed, but also carry the torque of the load. Acceleration time then is:

$$t = \frac{WK^2\ \Delta RPM}{g\ (\text{clutch torque - load torque})}$$

The above formula indicates that when the rated torque of the chosen clutch is close to the load torque, the acceleration period and hence the heat generated will be large. In such a case, a larger clutch is recommended. If any part of the load is to operate at a speed other than clutch speed, WK^2 must be compensated by means of Formula 2:

For occasional start stop, if possible, put the clutch or brake on the high speed shaft where torque is lowest.

High inertia start/stop applications involve heavy rotating rolls or flywheels. Engagement is infrequent but takes longer than in category #1, occasional start/stop. Any situation where the start/stop period is more than ½ second should definitely be brought under this category.

Formula 1

1E

$$T = \frac{WK^2(\Delta RPM)}{25.6\ (t)}$$

Where
T (In Lb), WK^2 (Lb Ft^2), t (sec)

1M

$$T = \frac{WK^2(\Delta RPM)}{9.55\ (t)}$$

Where
T (NM), WK^2 (KgM^2),t (sec)

Again, Formula 2 has to be used along with Formula 1 for parts driven by clutch and not rotating at clutch speed.

Any body which goes through a change in RPM undergoes a change of kinetic energy:

$$KE = \frac{WK^2\ (RPM_2^{\,2} - RPM_1^{\,2})}{2g} \qquad \text{Formula } \mathbf{5}$$

5E

$$KE = \frac{WK^2\ (RPM_2^{\,2} - RPM_1^{\,2})}{5{,}868}$$

Where
KE (FtLb), WK^2 ($LbFt^2$)

5M

$$KE = \frac{WK^2\ (RPM_2^{\,2} - RPM_1^{\,2})}{183}$$

Where
KE (Joule), WK^2 (KgM^2)

Each time the rotating parts change speed or are brought to a stop, heat equivalent to this energy is generated at the clutch (or brake) interface. In high inertia applications, clutch/brake heat sink values can be utilized, because the unit has time to cool between starts and stops. The clutch or brake is to be sized such that the rated heat sink value on Table 3 exceeds the value from Formula 5.

EXAMPLE:

A flywheel with a WK^2 value of 4,000 $LbFt^2$ (169 KgM^2) needs to be brought up to a speed of 1,375 RPM within two seconds. Size a Carlson Co. clutch for this application driven by a four-cylinder engine. All the driven and drive components are to be installed on the same shaft. 90 psi (6 Bar) air is available for the clutch.

SOLUTION:

The high WK2 value of 4,000 $LbFt^2$ (169 KgM^2), and an acceleration period longer than ½ second indicates that this application is in the "High inertia start/stop" category.

The first step is the determination of torque requirement using Formula 1

ENGLISH

$$T = \frac{(4{,}000)\ (1{,}375)}{25.6(2)} = 107{,}250 \text{ In Lb}$$

METRIC

$$T = \frac{(169)\ (1{,}375)}{9.55(2)} = 12{,}166 \text{ NM}$$

Since the prime mover is a four-cylinder engine operating above 700 RPM, a safety factor of 2.2 is recommended. So torque requirement=107,250 (2.2)=235,950 InLb (26,765 NM). A Carlson Co. model CW clutch is suitable for this application since there is a flywheel to which the clutch can be mounted on directly. A 25" clutch can be selected, which has a rating of 237,227 In Lb @ 90 psi (26,802 NM @ 6 Bar).

The heat sink requirement is determined using Formula 5

ENGLISH

$$KE = \frac{4{,}000(1{,}375\text{-}0^2)}{5{,}868} = 1{,}285{,}000 \text{ Ft Lb}$$

METRIC

$$KE = \frac{169\ (1{,}375^2\text{-}0^2)}{183} = 1{,}746{,}000 \text{ Joule}$$

A Carlson Co. 25 CW clutch has a rated heat sink value (Table 3)=10 million ft-lb (13.6 million Joule). The chosen clutch has the heat capacity required for this application. Therefore, the selection is a 25 CW clutch.

CYCLIC START-STOP applications are encountered in process machinery where stock is precisely located and then sheared stamped or formed. In contrast to the `Infrequent Engagement' category, the cycling rate of the clutch in this category is at least seven times an hour.
First the clutch is sized based on torque requirement calculated using Formulas 1 and 2.

Next the heat dissipation capacity of the clutch must be compared to the heat generated in the application.

$$P = \frac{WK^2 \left(RPM_2^{\,2} - RPM_1^{\,2}\right)(f)}{2g} \quad \text{Formula } \mathbf{6}$$

6E

$$P = \frac{WK^2 \left(RPM_2^{\,2} - RPM_1^{\,2}\right)(f)}{1.936 \times 10^8}$$

Where
P (HP), WK^2 (Lb Ft^2), f (Cycles/Min.)

6M

$$P = \frac{WK^2 \left(RPM_2^{\,2} - RPM_1^{\,2}\right)(f)}{10.9 \times 10^6}$$

Where
P (KW), WK^2 (KgM^2), f (Cycles/Min.)

The factory should be consulted to determine if the rated heat dissipation value of the chosen clutch is enough to meet the thermal HP requirement calculated using Formula 6.

EXAMPLE:
Calculate the continuous heat dissipation requirement of a clutch which is required to bring a load inertia of 1,000 $LbFt^2$ (42.2 KgM^2) from rest to 1,800 RPM every six minutes.

SOLUTION:

Find the continuous heat dissipation required using formula 6.

ENGLISH $$P = \frac{1{,}000 \left(1{,}800^2 - 0\right) .166}{1.936 \times 10^8} = 2.8 \text{ HP}$$

METRIC $$P = \frac{42.2 \left(1{,}800^2 - 0\right) .166}{10.9 \times 10^6} = 2.1 \text{ KW}$$

TABLE 1

STATIC TORQUE In Lb (NM) VS. AIR PRESSURE PSI (BAR)

USING STANDARD LINING (.42 COEFFICIENT OF FRICTION)

	SIZE											
PSI (Bar)	8.5	10	12	14	16	18	20	22	25	28	32	36
10	330	1031	1454	3386	4214	7681	8673	14027	21008	34557	43169	73992
(0.68)	(37.3)	(116.5)	(164.3)	(382.6)	(476.2)	(867.9)	(980)	(1585.1)	(2373.9)	(3904.9)	(4878.1)	(8361.1)
20	896	2336	3721	7695	10497	17682	21369	32469	48035	75828	100055	163370
(1.36)	(101.2)	(263.9)	(420.5)	(869.5)	(1186.2)	(1998)	(2414.7)	(3668.9)	(5427.9)	(8568.6)	(11306.2)	(18460.8)
30	1462	3642	5988	12004	16781	27682	34065	50911	75063	117090	156941	252748
(2.04)	(165.2)	(411.5)	(676.6)	(1356.5)	(1896.3)	(3128.1)	(3849.3)	(5752.9)	(8482.1)	(13231.2)	(17734.3)	(28560.5)
40	2027	4947	8254	16313	23064	37682	46760	69352	102090	158370	213826	342126
(2.72)	(229.1)	(559)	(932.7)	(1843.4)	(2606.2)	(4258.1)	(5283.8)	(7836.8)	(11536.2)	(17895.8)	(24162.3)	(38660.2)
50	2593	6253	10521	20621	29347	47683	59456	87794	129118	199641	270712	431504
(3.4)	(293)	(706.6)	(1188.9)	(2330.1)	(3316.2)	(5388.2)	(6718.5)	(9920.7)	(14590.3)	(22559.4)	(30590.5)	(48759.9)
60	3158	7558	12788	24930	35630	57683	72152	106236	156145	240912	327598	520881
(4.08)	(356.9)	(854.1)	(1445)	(2817.1)	(4026.2)	(6518.2)	(8153.2)	(12004.7)	(17644.4)	(27223.1)	(37018.6)	(58859.5)
70	3724	8864	15055	29239	41913	67684	84847	124678	183172	282183	384484	610259
(4.76)	(420.8)	(1001.6)	(1701.2)	(3304)	(4736.69)	(7648.3)	(9587.7)	(14088.6)	(20698.4)	(31886.7)	(43446.7)	(68959.3)
80	4290	10169	17322	33548	48196	77684	97543	143120	210200	323454	441370	699637
(5.44)	(484.8)	(1149.1)	(1957.4)	(3790.9)	(5446.1)	(8778.3)	(11022.4)	(16172.6)	(23752.6)	(36550.3)	(49874.8)	(79058.9)
90	4855	11475	19588	37857	54479	87685	110239	161562	237227	364725	498256	789015
(6.12)	(548.6)	(1296.7)	(2213.4)	(4277.8)	(6156.1)	(9908.4)	(12457)	(18256.5)	(26806.7)	(41213.9)	(56302.9)	(89158.7)
100	5421	12780	21855	42166	60762	97685	122935	180004	264255	405996	555142	875393
(6.8)	(612.6)	(1444.1)	(2469.6)	(4764.8)	(6866.1)	(11038.4)	(13891.7)	(20340.5)	(29860.8)	(45877.5)	(62731)	(98919.4)
110	5986	14086	24122	46475	67045	107686	135630	198445	291282	447267	612028	967771
(7.48)	(676.4)	(1591.7)	(2725.8)	(5251.7)	(7576.1)	(12168.5)	(15326.2)	(22424.3)	(32914.9)	(50541.2)	(69159.2)	(109358.1)
120	6552	15391	26389	50784	73328	117686	148326	216887	318310	448538	668914	1057149
(8.16)	(740.4)	(1739.2)	(2981.9)	(5738.6)	(8286.1)	(13298.5)	(16760.8)	(24509.2)	(35968)	(50684.8)	(75587.3)	(119457.8)

TABLE 2

FOR TENSION OR CONTINUAL SLIP APPLICATION

DYNAMIC TORQUE In Lb (NM) VS AIR PRESSURE PSI (Bar) USING LO(CO LINING (.139 COEFFICIENT OF FRICTION)

	SIZE											
PSI (Bar)	8.5	10	12	14	16	18	20	22	25	28	32	36
10	109	341	481	1121	1395	2542	2870	4642	6953	11437	14287	24488
(0.68)	(12.3)	(38.5)	(54.4)	(126.7)	(157.6)	(287.2)	(324.3)	(524.5)	(785.7)	(1292.4)	(1614.4)	(2767.1)
20	297	773	1231	2547	3474	5852	7072	10746	15897	25096	33113	54068
(1.36)	(33.6)	(87.3)	(139.1)	(287.8)	(392.6)	(661.3)	(799.1)	(1214.3)	(1796.40)	(2835.8)	(3741.8)	(6109.7)
30	484	1205	1982	3973	5554	9161	11274	16849	24842	38754	51940	83647
(2.04)	(54.7)	(136.2)	(224)	(449)	(627.6)	(1035.2)	(1274)	(1904)	(2807.1)	(4379.2)	(5869.2)	(9452.1)
40	671	1637	2732	5399	7633	12471	15474	22952	33787	52413	70766	113227
(2.72)	(75.8)	(184.9)	(308.8)	(610.1)	(862.5)	(1409.2)	(1748.6)	(2593.6)	(3818)	(5922.7)	(7996.5)	(12794.6)
50	858	2069	3482	6825	9712	15781	19677	29056	42732	66072	89593	142807
(3.4)	(96.9)	(233.8)	(393.5)	(771.2)	(1097.5)	(1783.3)	(2223.5)	(3283.3)	(4828.7)	(7466.1)	(10124)	(16137.2)
60	1045	2501	4232	8251	11792	19090	23879	35159	51677	79730	108419	172387
(4.08)	(118.1)	(282.6)	(478.2)	(932.4)	(1332.5)	(2157.2)	(2698.3)	(3973)	(5839.5)	(9009.5)	(12251.3)	(19479.7)
70	1232	2933	4982	9677	13871	22400	28080	51262	60621	93389	127246	201967
(4.76)	(139.2)	(331.4)	(563	(1093.5)	(1567.4)	(2531.2)	(3173	(5792.6	(6850.2)	(10553)	(14378.8)	(22822.3)
80	1420	3366	5733	11103	15951	25710	32282	47366	69566	107048	146072	231547
(5.44)	(160.5)	(380.3)	(647.8)	(1254.6)	(1802.5)	(2905.2)	(3648	(5352.4)	(7860.9)	(12096.4)	(16506.1)	(26164.8)
90	1607	3798	6483	12529	18030	29019	36484	53469	78511	120707	164899	261126
(6.12)	(181.6)	(429.2)	(732.6)	(1415.8)	(2037.4)	(3279.1)	(4122.7)	(6042)	(8871.7)	(13639.9)	(18633.6)	(29507.2)
100	1794	4230	7233	13955	20109	32329	40686	59573	87456	134365	183725	290706
(6.8)	(202.7)	(478)	(817.3)	(1577	(2272.3)	(3653.2)	(4597.5)	(6731.7)	(9882.5)	(15183.2)	(20760.9)	(32849.7)
110	1981	4662	7983	15381	22189	35639	44887	65676	96401	148024	202552	320286
(7.48)	(223.9)	(526.8)	(902.10	(1738.1)	(2507.4)	(4027.2)	(5072.2)	(7421.4)	(10893.3)	(16726.7)	(22888.4)	(36192.3)
120	2168	5094	8733	16807	24268	38949	49089	71779	105345	161683	221379	349866
(8.16)	(244.90)	(575.6)	(986.8)	(1899.2)	(2742.3)	(4401.2)	(5547.1)	(8111)	(11903.9)	(18270.2)	(25015.8)	(39534.9)

TABLE 3

RATED HEAT SINK VALUE

CLUTCH SIZE	KINETIC ENERGY ABSORTION MILLION OF FT-LB (MILLION OF JOULE)	SHOE BRAKE SIZE	KINETIC ENERGY ABSORPTION MILLION OF FT-LB (MILLION OF JOULE)
8.5 10 12 14	.71 (.97) .89 (1.21) 1.52 (2.07) 1.95 (2.65)	7 10 14 18 24	.35 (.476) 1.06 (1.44) 2.83 (3.85) 4.78 (6.50) 14.16 (19.26)
16 18 20 22	2.88 (3.92) 3.82 (5.20) 5.44 (7.40) 6.53 (8.88)		
25 28 32 36	10.00 (13.60) 14.27 (19.41) 20.58 (28.20) 30.84 (41.94)		

Continuous Slip applications always require a high heat dissipation capacity of the clutch or brake. LO-CO LINING (coefficient of friction=.14) must be specified for slip applications.
A common slip application is the tension control of winding or unwinding rolls of paper, fabric, foils, etc. The following data is required to size a clutch or brake for this type of application.

1. Roll diameter (O.D.)
2. Core diameter (I.D.)
3. Web Width(W)
4. Unit Web Tension (U)
5. Web Speed (S)

From these calculate secondary data

1. Web Tension = W (U)
2. Maximum Torque = O.D. (W) (U)/2
3. Minimum Torque = I.D. (W) (U)/2
4. Maximum RPM = S/ π I.D.
5. Minimum RPM = S/ π O.D.

WINDING (CLUTCH):
A winding operation is usually done by turning the input to the clutch at a constant RPM and driving the wind-up roll with the output side of the clutch. The slip RPM increases as the roll builds up. First calculate the heat to be dissipated.
Slip clutch heat

$$P = \text{Maximum Torque } (RPM_{in} - \text{Min RPM}) \qquad \textbf{Formula 7}$$

7E

$$P = \frac{O.D.\ (W)\ (U)}{126{,}050}\left(RPM_{in} - \frac{12\ (S)}{\pi O.D.}\right)$$

Where
P (HP), O.D. (In), W In), U (Lb/In), S (Ft/Min)

7M

$$P = \frac{O.D.\ (W)\ (U)}{10{,}620}\left(RPM_{in} - \frac{60\ (S)}{\pi O.D.}\right)$$

Where
P (KW), O.D. (M), W (M), U (N/M), S (M/sec)

The heat dissipation capacity of the clutch increases with it's RPM.
Use the capacity at the minimum RPM.
Next check that the maximum and minimum torques are both within the clutch capacity with engagement pressures from 6 - 60 PSI, and with LO-CO lining.

UNWIND (BRAKE):
An unwind operation is usually done by applying brake torque to the roll producing the desired web tension.
The slip RPM increase as the roll gets smaller. Most unwind operation are considered constant velocity.

Slip brake heat

$$P = W\ (U)\ S \qquad \textbf{Formula 8}$$

8E

$$P = \frac{W\ (U)\ S}{33{,}000}$$

Where
P (HP), W (In), U (Lb/In), S (Ft/ Min)

8M

$$P = \frac{W\ (U)\ S}{556}$$

Where
P (KW), W (M), U (N/M), S (M/sec)

EXAMPLE 1
What is the torque and dissipation capacity required for a clutch on a winding application of brass sheet. The core diameter is 10" (.254 M) and is it is rolled up to 36" (.914 M) diameter. The material is 60" (1.524 M) wide and has a unit tension of 15 Lb/In (2,627 N/M). Web speed is 200 Ft/Min (1.02 M/sec). Input RPM is 75.

SOLUTION:

$$\text{MAXIMUM TORQUE} = \frac{O.D.\ (W)\ U}{2}$$

ENGLISH

$$\frac{36\ (60)\ 15}{2} = 16{,}200 \text{ In Lb}$$

METRIC

$$\frac{.914\ (1.524)\ 2{,}627}{2} = 1{,}830 \text{ NM}$$

MINIMUM RPM = S/ π (O.D.)

ENGLISH

$$\text{MINIMUM RPM} = \frac{36\ (12)}{\pi\ (36)} = 21 \text{ RPM}$$

METRIC

$$\text{MINIMUM RPM} = \frac{1.02\ (60)}{\pi\ (.914)} = 21 \text{ RPM}$$

Find heat dissipation required using formula 7

ENGLISH

$$P = \frac{36(60)(15)}{126{,}050}(75-21)$$

$$= .257\ (54) = 13.9 \text{ HP}$$

METRIC

$$P = \frac{.914(1.524)2{,}627}{10{,}620}(75-21)$$

$$= .345\ (54) = 18.61 \text{ KW}$$

Note: The clutch for this application must be able to dissipate the above power @ 22 RPM.

EXAMPLE 2: What is the torque and heat dissipation requirements for a brake tensioning a paper roll unwind. Web speed is 600 Ft/ Min (3 M/sec)
The roll diameter is 72" (1.83 M) and the core diameter is 10" (.254M) The material is 60" (1.524 M) wide and has a unit tension of 1.665 Lb/In (289 N/M).

SOLUTION:

$$\text{MAXIMUM TORQUE} = \frac{O.D.\ (W)\ U}{2}$$

ENGLISH

$$\frac{72\ (60)\ 1.65}{2} = 7{,}128 \text{ InLb}$$

METRIC

$$\frac{1.83\ (1.524)\ 289}{2} = 806 \text{ NM}$$

MINIMUM RPM = S/ π (O.D.)

ENGLISH

$$\frac{600\ (12)}{\pi(72)} = 32 \text{ RPM}$$

METRIC

$$\frac{3\ (60)}{\pi(1.83)} = 32 \text{ RPM}$$

Find heat dissipation required using formula 8.

ENGLISH

$$P = \frac{W(U)S}{33{,}000} = \frac{60\ (1.65)\ 600}{33{,}000} = 1.8 \text{ HP}$$

METRIC

$$P = \frac{W(U)S}{556} = \frac{1.524\ (289)\ 3}{556} = 2.38 \text{ KW}$$

Note: The brake for this application must be able to dissipate the above power @ 32 RPM.

WK2 OF STEEL DISC

To determine the WK^2 of a given diameter of disc: multiply the WK^2 value below by the length of the disc.
For hollow shafts, subtract WK^2 of the inside diameter from WK^2 of the outside diameter and multiply by length.
The chart values were generated using the following.

ENGLISH

$$\frac{WK^2}{IN} = \frac{D^4}{5195}$$

Where WK^2 = $LbFt^2$
D = In

For Conversion, Lb Ft^2 X .04218 = KgM^2

METRIC

$$\frac{WK^2}{M} = 770\ D^4$$

Where WK^2 = KgM^2
D = M

DIAMETER (In)	WK^2 (Lb $Ft.^2$)	DIAMETER (M)	WK^2 (KgM^2)
2	.00310	.050	.0048
2-1/2	.00752	.060	.0100
3	.0156	.070	.0185
3-1/2	.029	.080	.0315
4	.049	.090	.0505
4-1/2	.079	.100	.077
5	.120	.110	.113
5-1/2	.177	.120	.160
6	.250	.130	.220
6-1/2	.345	.140	.296
7	.464	.150	.390
7-1/2	.611	.160	.505
8	.791	.170	.643
8-1/2	1.00	.180	.808
9	1.27	.190	1.000
9-1/2	1.55	.200	1.23
10	1.93	.225	1.97
11	2.83	.250	3.01
12	4.00	.275	4.40
13	5.58	.300	6.24
14	7.42	.325	8.59
15	9.75	.350	11.55
16	12.61	.375	15.23
17	16.07	.400	19.71
18	20.21	.425	25.12
19	25.08	.450	31.58
20	30.79	.475	39.20
21	37.43	.500	48.12
22	45.09	.525	58.50
23	53.87	.550	70.46
24	63.86	.575	84.17
25	75.19	.600	99.79
26	87.96	.625	117.49
27	102.30	.650	137.45
28	118.31	.675	159.85
29	136.14	.700	184.88
30	155.92	.725	212.74
31	177.77	.750	243.63
32	201.8	.775	277.78
33	228.2	.800	315.39
34	257.2	.825	356.70
35	288.8	.850	401.94
36	323.2	.875	451.36
37	360.7	.900	505.20
38	401.3	.925	563.71
39	445.3	.950	627.17
40	492.8	.975	695.84
		1.000	770.00

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